Xenon components in Martian Meteorites: Evidence for atmospheric evolution?

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Most SNC meteorites have young solidification ages which imply large-scale outgassing of the parent body during magmatic activity. Xe isotopic signatures observed in these meteorites not only have the potential of tracing the evolution of a planet's atmosphere but also might help to establish relationships among the solar system reservoirs. New measurements of N and Xe in ALH84001, EET79001 and Zagami provide additional constraints. Our results show varying $^{129}Xe/^{132}Xe$ ratios due to component mixtures, but suggests that the Martian atmospheric Xe component evolved early on. Shifts in the heavy Xe isotopes due to additional fission components are small. The atmospheric component may be characterized as solar-type Xe, but mass fractionated by 3.75 % per amu.

Mars is generally considered to be the parent body of the SNC meteorites [1, 2]. Noble gas and N measurement in glass separates of EET79001 and Zagami provide strong supporting evidence for a Martian origin of these meteorites. Measured isotopic and elemental ratios of noble gases and N [3, 4, 5, 6] in these members of the SNC meteorites are strikingly similar to the Viking data of the Martian atmosphere [7]. We carried out additional measurements on specific lithologies of Zagami, EET79001 and bulk ALH84001. Samples were heated at progressively higher temperatures, the gases released by pyrolysis or combustion were separated into Xe and N_2 fractions which were analyzed in a static mass spectrometer following standard procedures [6]. Here we present Xe isotopic systematics of all SNC data obtained so far.

Fig. 1 shows the isotopic ratios $^{130}Xe/^{136}Xe$ vs. $^{132}Xe/^{136}Xe$. Individual temperature steps are plotted after subtracting the cosmogenic component, based on the $^{126}Xe/^{136}Xe$ ratio (adopted from SPB-Xe [5]) and using the Xe spallation spectra deduced from Stannern [8], a basaltic meteorite. Excluding low-temperature steps, literature data on ALH84001, EET79001 (lithologies A, B, and C), ALH77005, Shergotty, Nakhla, and Chassigny [4, 5, 9, 10, 11] are included for comparison, after subtracting the cosmogenic component in the same manner. However, in the case of Chassigny solar Xe was used as the trapped composition. The direction of shifts expected due to addition of fission Xe from ^{244}Pu and ^{238}U, or HL-Xe to solar Xe are indicated. Fig. 1 shows that the extent of mass fractionation required to account for Martian atmospheric data in SNC's is larger than that of terrestrial atmospheric Xe. We calculate a fractionation of 3.75 % per amu for the composition M.NR (Mars Non-Radiogenic) on the mass fractionation line (m.f.) of solar Xe. The adopted $^{132}Xe/^{136}Xe$ = 2.87 is the average ratio observed in the atmospheric components of Zagami and EET79001 (Fig.2). The Xe data are consistent with mixtures of two components with Chassigny as one and EET79001/Zagami the other end member. Minor shifts from the tie-line may be due to addition of fission Xe from ^{244}Pu or ^{238}U and/or HL-Xe. It is significant that solar Xe fits closely the Chassigny data and at the same time represents the end-member composition.

Fig. 2 shows the plot of $^{132}Xe/^{136}Xe$ vs. $^{129}Xe/^{136}Xe$. The cluster of points at bottom right, consisting of EET79001 and Zagami data, correspond to the highest $^{129}Xe/^{136}Xe$ ratios measured in the SNC meteorites. They are taken to represent the recent (and present) Martian atmospheric composition. The data reveal the presence of another component, possibly an indigenous trapped component, which is much less radiogenic than the atmospheric component, but has a similar ^{132}Xe/^{136}Xe ratio.

Among the SNC meteorites the presence of an atmospheric component is well established in the shock-produced glasses of Zagami and EETA79001, as well as in a currently unknown carrier phase of ALH84001. Fig. 2 also reveals that the ^{129}Xe/^{136}Xe ratio in ALH84001 is lower than those in Zagami and EET79001. This may either reflect the incorporation of different atmospheric Xe in the case of ALH84001, or the incomplete separation of an indigenous component. Since the closure times for these meteorites probably differ, this may reflect a Xe evolution of the Martian atmosphere. However, it is not clear at present, when atmospheric gases were incorporated into these meteorites. Because of the short half-life of ^{129}I ($T_{1/2}$ = 16 Ma), which is the parent nuclide for ^{129}Xe, the ^{129}Xe/^{136}Xe ratio is likely to have evolved rapidly early in Martian history.

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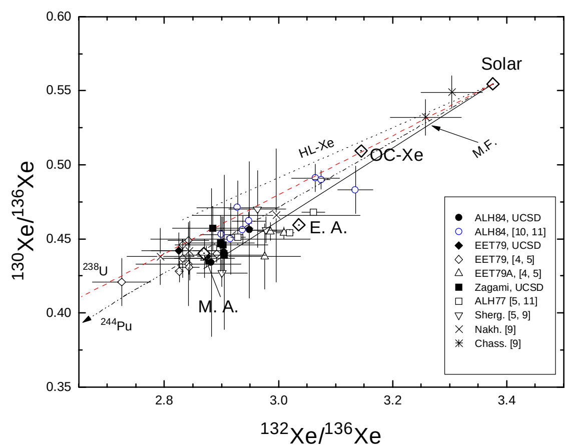

Fig. 1. Plot of the spallation corrected ^{130}Xe/^{136}Xe vs. ^{132}Xe/^{136}Xe in SNC meteorites. Filled symbols represent UCSD data and open symbols are from [4, 5, 9, 10, and 11], OC-Xe from [12], E.A. : Earth Atm.

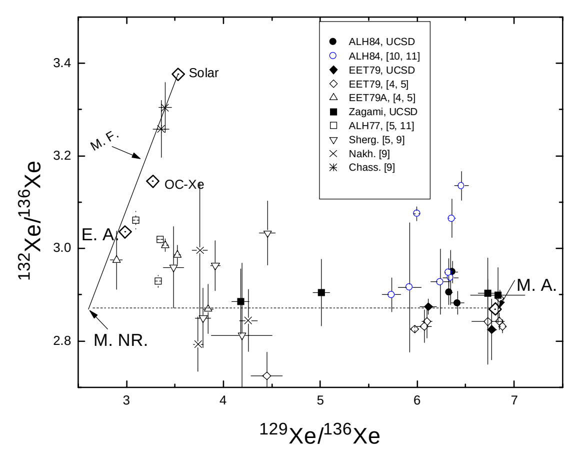

Fig. 2. ^{132}Xe/^{136}Xe and ^{129}Xe/^{136}Xe in SNC meteorites. All data, are corrected for the spallation component (see text). M. A. (Mars Atmosphere) is average of Zagami and EET79001 data. For references see Fig. 1.